April 19, 1860.

Sir BENJAMIN C. BRODIE, Bart., President, in the Chair.

Professor Auguste De la Rive, of Geneva, and Sir John Bowring, were admitted into the Society.

The CROONIAN LECTURE was then delivered by JAMES PETTIGREW, Esq., "On the Arrangement of the Muscular Fibres of the Ventricular portion of the Heart of the Mammal."

(Abstract.)

The Lecturer began by referring to the descriptions of the arrangement of the ventricular fibres of the heart given by previous inquirers, more especially Lower, Senac, Wolff, Gerdy, Duncan, and Reid; he then proceeded to give an account of the results of his own investigations, which had been conducted on the hearts of the Sheep, Calf, Deer, Ox, Horse, &c.; all of which, he observed, bear a perfect resemblance to the human heart*. In order, as much as possible, to overcome the difficulties of the subject, he availed himself of drawings, explanatory diagrams, and models illustrating the course and relation of the fibres. To these last, however, he observed he attached no special importance, further than that they were useful vehicles of communication; and it was to the dissections themselves, some of which were before the Society, that he looked for a corroboration of the statements he advanced.

Commencing with the left ventricle, which he believes to be the typical one, the Lecturer stated that, by exercising a little care, he had been enabled to unwind as it were its muscular substance, and so to separate its walls into several layers†, each of which is characterized by a difference in direction. Seven layers, at least, can be readily shown by dissection; but he believes they are in reality nine; viz. four external, the fifth or central, and four internal. He explained how the external fibres are continuous with the internal fibres at the apex, as was known to Lower‡, Gerdy§, and others,

* Mr. Pettigrew's researches include also the arrangement of the fibres in the ventricles of the Bird, Reptile, and Fish.

† Senac (Traité de la Structure du Cœur, &c. [Paris, 1749], planche 8) figures four layers; and Searle (Cyc. of Anat. and Phys., art. "Heart") speaks of three.

‡ Tractatus de Corde, &c. London, 1669.

§ Recherches, Discussions et Propositions d'Anatomie, Physiologie, &c. Paris, 1823.

and how the fibres constituting the several external layers are continuous with corresponding internal layers likewise at the base*,—a fact to which the Lecturer drew particular attention, as being contrary to the generally received opinion, which is to the effect that the fibres at the base are non-continuous, and arise from the auriculo-ventricular tendinous rings—which, as he showed by numerous dissections, is not the case.

Coming next to the question of the direction of the fibres, he showed how there is a gradational sequence in the direction of the fibres constituting the several layers. Thus the fibres of the first layer are more vertical in direction than those of the second, the second than those of the third, the third than those of the fourth, and the fourth than those of the fifth, the fibres constituting which layer are transverse, and run at nearly right angles to those of the first layer. Passing the fifth layer, which occupies the centre of the ventricular wall and forms the boundary between the external and internal layers, the order of things is reversed; and the remaining layers, viz. six, seven, eight, and nine, gradually return to the vertical in an opposite direction, and in an inverse order. This remarkable change in the direction of the external and internal fibres, which had in part been figured by Senac, and imperfectly described by Reid †, as well as other detached and important facts ascertained by himself and others—such as the continuity of the fibres at the apex and base, already adverted to—he suggested might be accounted for by the law of the double conical spiral, which he proceeded forthwith to explain.

The expression of the law, as he conceives it, with reference to the arrangement of the fibres in the ventricle, is briefly the following. By a simple process of *in*volution and *e*volution, the external fibres become *internal* at the apex, and *external* again at the base; so that whether the fibres be traced from without inwards, or from

* The late Dr. Duncan, Jun., of Edinburgh, was aware of the fibres forming loops at the base, but seems to have had no knowledge of the continuity being occasioned by the union of corresponding *external* and *internal* layers, or that these basal loops were prolongations of like loops formed by similar corresponding external and internal layers at the apex—a point which the Lecturer believes he is the first to establish.

† Cyc. of Anat. and Phys., art. "Heart." London, 1839.

within outwards, they always return to points not wide apart from those from whence they started. In order to illustrate the principle of the double conical spiral in the above sense, he took a sheet of net, through which parallel threads of coloured wool, representing the individual fibres, were drawn at intervals; and laying it out on the table before him, with the threads placed horizontally, seized it by the right-hand off corner, and rolled it in upon itself (*i. e.* towards his own body) seven turns, so as to produce a cone whose walls consisted of nine layers*. On gradually unwinding the walls of the cone thus fashioned (which is tantamount to undoing the spirals), so as to imitate the removal of consecutive layers from the walls of the ventricle, he finds that the gradation in the direction of the several layers just specified is distinctly marked; and that these layers, as was exhibited in various dissections, find a counterpart in the ventricle itself. Thus (the heart being supposed to be placed upright on its apex) in the first external layer the threads are seen running from base to apex, and from left to right †, almost vertically; in the second layer they are slightly oblique; this obliquity increases in the third, and still more in the succeeding layer, till in the fifth or central one the direction of the threads becomes transverse. After passing the central layer, the direction of the threads (as of the fibres) is reversed; in the sixth layer they begin to turn from *right* to *left*, with a slight inclination *upwards*; and in succeeding layers gradually become more and more vertical, until the innermost, or ninth, is reached, in which they become as vertical as in the first, but are curved in an opposite direction.

As a necessary consequence of this arrangement of the fibres, the Lecturer showed that when the layers are in apposition, as they exist in the undissected ventricle, the first external layer and the last internal cross each other with a slight deviation from the vertical, as in the letter X; while in the succeeding external and internal layers,

* A sheet of paper with parallel lines drawn upon it will answer the purpose equally well, except that its non-transparency precludes our seeing the external and internal spirals rolled the one within the other when the sheet is fashioned into a cone and held against the light, as the Lecturer recommends. The sheets should be twice as long as they are broad; and the lines or threads should run in the direction of the length.

† That is, in the direction from the left hand to the right of the observer.

until the fifth or central one, which is transverse, is reached, they cross at successively wider vertical angles, as may be represented by an ⋈ placed horizontally.

Holding the cone, prepared as described, against the light, the Lecturer then showed how, by the rolling process, a double system of conical spirals, similar to those found in the left ventricle, had been produced—the one an external left-handed down system, running from base to apex, and corresponding with the external layers ; the other an internal right-handed up system, running from apex to base, and corresponding with the internal fibres ; and how, seeing the opposite systems are the result of different portions of the same threads being rolled in different directions (the one within the other), the spirals are consequently continuous at the apex.

He in this manner explained the continuity of the external and internal fibres at the apex. By simply producing the threads forming the internal spirals, and turning them out at the base until they met corresponding external spirals, he next showed how the continuity of the fibres at the base might be accounted for. The connexion of the fibres at the base, he remarked, is effected for the most part as at the apex, by continuity of their proper muscular substance ; but those of the papillary muscles are continued by the tendinous cords. This continuity observes a certain order, so that certain external layers are continued at the apex into certain internal layers, and turn outwards at the base into their original external position. Thus the first layer is continuous with the ninth, the second with the eighth, the third with the seventh, and the fourth with the sixth, while the fifth occupies, as already said, the middle place between the four external and four internal. He thus endeavoured to prove that a strong analogy exists between the arrangement of the fibres at the apex and the base, and that the same principle which turns in the external fibres at the apex also turns out the internal at the base,—a view which, while it extends rather than militates against that of older writers, was strongly supported by the arguments he adduced. It would therefore seem that the fibres do not form simple loops pointing towards the apex, as generally supposed, but twisted continuous loops pointing alike to apex and base. From this arrangement, it follows that the first and ninth layers embrace in their convolutions those immediately beneath them, while these in

turn embrace those next in succession, and so on until the central layer is reached,—an arrangement which may in part explain alike the rolling movements and powerful action of the ventricles.

The Lecturer next drew attention to the manner in which the external fibres pass into the interior of the ventricle to form the musculi papillares. He first remarked that when the external fibres get into the interior they are necessarily confined to a smaller area, and are therefore crowded into a mass of greater thickness, which contributes to form the papillary muscles. He then showed that the external fibres, entering at the apex and forming the "vortex," pass inwards in two principal parcels or bundles, one of which comes chiefly from the posterior surface of the ventricle, and winds forwards to enter the apex anteriorly, whilst another comes from the anterior surface, and winds backwards to enter the apex posteriorly, a fact which the Lecturer believes has been hitherto overlooked. On entering the cavity, the anterior bundle crosses to the posterior wall, and forms the posterior papillary muscle, whilst the posterior bundle forms the anterior papillary muscle. The fact of this double entrance, and its relation to the papillary muscles, was shown in various preparations; and it was remarked that, but for this double entrance, which applies to all the external layers, the apex of the ventricle would be like the barrel of a pen cut slantingly, or, in fact, lop-sided; whereas, by the arrangement described, it is rendered bilaterally symmetrical.

To bring this bilateral entrance and symmetry into harmony with the description already given of the succession of layers, and with the illustration of the conically rolled sheet, the Lecturer explained that we must regard the primary sheet as having split into two, or we must suppose a second one superadded, and rolled up along with the first. In fact, if a second sheet of net with parallel threads be laid on the first, so that the threads upon it intersect those of the first at an acute angle, and the two are then rolled up together in the way already described, the result will be that the opening at the apex will have two symmetrical lips, as it were, representing the two parcels of fibres forming the vortex in the natural heart.

It is well known that the wall of the left ventricle is thickest at about a third of its length from the base, and that from this point it decreases in thickness towards the base, and still more towards the

apex, which is its thinnest part. This condition may be explained by a certain modification of the preceding description,—by supposing, namely (what is really the fact), that the outermost and innermost layers extend further towards the apex and towards the base than those which come next, and these again further than those which succeed, and so on with the rest; the central one being of least extent, and confined indeed to about the middle third of the ventricle. In this way the ventricular wall is thickest towards its middle, where it is composed of all the layers, but becomes thinner and thinner towards the base and apex, where it consists of fewer and fewer layers.

Proceeding next to speak of the right ventricle, and especially of its relation to the left, the Lecturer observed that the simplest way to view that ventricle is to regard it as a segment of the left one; and this view he considers to be most in accordance with what we know of its structure and mode of development. For a short time after the heart appears in the embryo, its ventricular compartment is simple; but a septum soon begins to rise up within it, which proceeds from the right side of the apex and anterior wall of the cavity in the direction of the base, and is completed about the eighth week of intra-uterine life. For a time, moreover, the new-formed ventricles have equally thick walls; but as the full period is approached, the left, which is destined after birth to perform a larger amount of work, comes to predominate in thickness. Starting now from the left or "typical" ventricle, constituted as above described, the Lecturer showed that, by pushing in the anterior wall in imitation of the constructive process in the embryo until it reaches the posterior wall, two ventricles are produced, with a partition or septum between. As, however, the septum in this case is double and unattached posteriorly, he said it was necessary, in order to complete the structure, to suppose the fibres forming the posterior border of the septal duplicature as coalescing or anastomosing with corresponding fibres of the posterior wall, whilst the fibres of the two halves of the duplicature itself are blended with each other. In this way, as he explained, there results a single septum connected posteriorly, and constituted in a manner which remarkably accords with the structure discovered by dissecting the adult heart. Thus, when both ventricles are dissected at the same time, the fibres forming the

external layers posteriorly are found to be for the most part common to both; in other words, the fibres on the back part of the left ventricle cross over the posterior coronary tract, and pass on to the right ventricle; whereas, in front, with the exception of a large cross band at the base, the fibres of the right and of the left ventricle respectively dip inward at the anterior coronary tract, as if altogether independent of each other: an arrangement which induced Winslow to regard the heart as consisting of two muscles enveloped in a third. When, moreover, the so-called common fibres, posteriorly, are dissected layer by layer simultaneously with the independent anterior fibres, it is found that both pass through the same changes of direction; and the same rule holds good with the fibres of the septum.

Another possible mode of explaining the septum, as the Lecturer showed, is to regard the layers entering into the formation of the left ventricle as splitting up posteriorly, the one half of each layer winding round to form the right ventricle, and then dipping in front to form the right half of the septum, whilst the other half proceeds immediately forwards to form the left half of the septum.

Both ventricles thus appear to be formed on the same general plan, but they differ materially in the structure of their apices; and the question arises—which is the *primary* or *typical ventricle*? Now, while the fibres of the left ventricle enter its apex in a spiral manner by a species of involution similar to that which would be produced by rolling a sheet of muscle into a cone, those of the right ventricle simply bend or double on themselves. Moreover, as the Lecturer suggested, were we to split the septum into two, assigning to each ventricle its proper share, and then apply the cut ends of the common fibres (which cross from the left to the right ventricle posteriorly) to their corresponding fibres in the left half of the septum, we should find that we had still a perfect whole—in other words, a complete system of external and internal spirals; whereas the fibres of the right ventricle and its half of the septum, treated in the same way, would represent only a part of a more complete system—a portion nipped off, as it were, from the side of the perfect cone. Accordingly, if we would dissect the left ventricle, and especially its apex, symmetrically, we must detach the right ventricle as if it were of no account, and dissect layer after layer of the septum *pari passu* with the layers of the left ventricular wall generally; on the other

hand, the right ventricle can be dissected only in connexion with the left.

For these reasons the Lecturer is inclined to regard the left ventricle as the typical one, and the right as a mere segment thereof; and in further corroboration of this opinion, he referred to the shape of the right and left ventricular cavities, as shown by casts of their interior. The left always yields a beautifully finished and perfect right-handed conical screw, while the cast of the right ventricle, although it has the same twist, represents only an incomplete portion. This statement was illustrated by a wax-cast of the ventricles of the heart of a deer.

In conclusion, the Lecturer remarked that the arrangement of the fibres composing the ventricles of the mammalian heart, as he had endeavoured to expose it, is characterized by comparative simplicity, and harmonizes perfectly with what is known of the heart's movements.

[The matters touched on by the Lecturer are more fully treated of, and the descriptions copiously illustrated by figures, in his Paper entitled "On the Arrangement of the Muscular Fibres of the Ventricular Portion of the Vertebrate Heart." By JAMES PETTIGREW, Esq. Communicated by JOHN GOODSIR, Esq., Professor of Anatomy in the University of Edinburgh. Received Nov. 22, 1859.]

April 26, 1860.

Sir BENJAMIN C. BRODIE, Bart., President, in the Chair.

The following communications were read:—

I. "Note on Regelation." By MICHAEL FARADAY, D.C.L., F.R.S. &c. Received March 13, 1860.

The philosophy of the phenomenon now understood by the word Regelation is exceedingly interesting, not only because of its relation to glacial action under natural circumstances, as shown by Tyndall and others, but also, and as I think especially, in its bearings upon molecular action; and this is shown, not merely by the desire of dif-